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# Laser Induced Aluminum Surface Breakdown Model

Progress Report

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Prepared for

**National Aeronautics and Space Administration**
**George C. Marshall Space Flight Center**
**Marshall Space Flight Center, AL 35812**

by

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September 15, 2001

# Laser Induced Aluminum Surface Breakdown Model

## OBJECTIVES

Laser powered propulsion systems involve complex fluid dynamics, thermodynamics and radiative transfer processes. Based on an unstructured grid, pressure-based computational aerothermodynamics platform, several sub-models describing such underlying physics as laser ray tracing and focusing, thermal non-equilibrium, plasma radiation and air spark ignition have been developed. This proposed work shall extend the numerical platform and existing sub-models to include the aluminum wall surface Inverse Bremsstrahlung (IB) effect from which surface ablation and free-electron generation can be initiated without relying on the air spark ignition sub-model. The following tasks will be performed to accomplish the research objectives.

## TASKS PERFORMED IN THIS REPORTING PERIOD

In this reporting period, mechanisms for initializing the aluminum surface ablation and ionization due to focused laser energy is formulated and planned for computer coding implementation. At the start of the laser pulse, the beams are focused at a small area on the aluminum surface of the test vehicle. Part of the energy is absorbed by the material and causes to overcome the bounding energy of the molecules. This process is accounted for through stopping power as described by Harada [1 – 4]. In the present model, the energy absorbed, as output from the radiation model, is used to calculate the evaporation rates of the aluminum material from the surface. The ionization of the ablated material is then initiated by using the Saha's equation under the thermal and chemical equilibrium assumption [4].

The UNIC-UNS pulsed laser supported propulsion numerical model is further modified to enable parallel computing for efficient computations, especially for three-dimensional models. The ray tracing radiative heat transfer model, laser ray inlet boundary conditions, laser reflection conditions, thrust force time integration and performance data integration are implemented to work in parallel computing environment. Full 3D ray tracing radiation model is also implemented in this task. This model has been tested successfully using 2D and 3D laser lightcraft model-A configuration and test conditions.

A new treatment for modeling the laser absorption when the local electron number density reaches the resonant critical value has been developed to remove the difficulty of calculating short pulse width conditions due to very high laser power. Previously, a

resonant absorption constant is assumed as soon as the local electron number density reaches the critical value. This creates a step jump in energy input to the local computational cells and causes the instability of the numerical model. To circumvent this problem, a smooth variation in the energy absorption is assumed before the laser rays reach the plasma resonance front. This smooth absorption function is constructed based on the electron number density. Preliminary calculation using this treatment showed increased integrated thrust coupling coefficients for normal pulse width cases. Test for a short pulse-width case (with 1 microsecond pulse width) has shown good stability of the computational model. Fine-tuning of this treatment is necessary to anchor the modeling constants for its applicability over a selected range of pulse widths and power levels.

References


1. Harada, Nob., Kagihiro, M., Shinkai, H., Jiang, W. and Yatsui, K., "Flyer Acceleration by Ablation Plasma Using an Intense Pulsed Ion Beam," AIAA 99-3485, 30th Plasmadynamics and Lasers Conference, 28 June – 1 July, 1999, Norfolk, VA.
2. Harada, Nob., Yazawa, M., Kashine, K., Jiang, W. and Yatsui, K., "Numerical Simulation of Foil Acceleration by Intense Pulsed Ion Beam," AIAA 2000-2272, 31st AIAA Plasmadynamics and Lasers Conference, 19-22 June, 2000, Denver, CO.
3. Harada, Nob., "Acceleration of Multi-Layer Foil by Intense Pulsed Ion Beam," AIAA 2001-3005, 32nd AIAA Plasmadynamics and Lasers Conference, 11-14 June, 2001, Anaheim, CA.
4. Harada, Nob., (Private Communication), September, 2001.


## TASKS TO BE PERFORMED IN THE NEXT PERIOD

1. Perform calculation of aluminum surface ablation and ionization with laser energy input.
2. Continue computation of short pulse width cases and to fine-tune the resonant laser absorption model.

## CONTRACT PERFORMANCE AND FUNDING

30% of the proposed technical effort has been accomplished with 30% of the funding billed. No technical problem of the current model development has been encountered.

**ESI**

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September 15, 2001

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From: Yen-Sen Chen, Engineering Sciences, Inc., Huntsville, Alabama

Subject: Interim Technical Report for the Order No. H-33325D
-- LASER INDUCED ALUMINUM SURFACE BREAKDOWN MODEL

Sincerely,

ESI

Yen-Sen Chen
President

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